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HEAT ADAPTATION IN CENTRAL ASIA

HOUSEHOLD COOLING CHOICES

Burulcha Sulaimanova, Dina Azhgaliyeva, Hans Holzhacker, and Indra Overland

NO. 787

June 2025

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ASIAN DEVELOPMENT BANK

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ABSTRACT

This study investigates factors influencing household cooling choices in Central Asia, focusing on air-conditioning and fans/sunscreen films. Using data from the 2023 "Household Access to Energy in the Fergana Valley" survey in the Kyrgyz Republic, Tajikistan, and Uzbekistan, the analysis employs a multinomial probit model to examine socioeconomic, environmental, and power supply factors. Across the three countries, it finds that 48% of households use fans or sunscreen films (without air-conditioning), 30% use no cooling, and 22% use air-conditioning, noting significant variations between countries. Cooling degree days (CDD) significantly impact cooling appliance adoption, with higher CDD regions more likely to use cooling solutions. Power outages negatively affect air-conditioning adoption but not fans/sunscreen films, highlighting the importance of power stability. Robustness checks confirm that power supply reliability is crucial for cooling choices. The findings suggest policy implications, including the potential of solar panels to meet summer energy demands. This research underscores the need to address power sector reliability and climate adaptation in vulnerable regions.

Keywords: heat waves, environmental extremes, infrastructural adaptations, power outages, cooling technologies, Central Asia

JEL codes: Q41, R21, Q54

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1. Introduction

The rapid global temperature rise due to climate change has significantly increased demand for cooling technologies, particularly in regions susceptible to extreme heat waves (Thomson et al., 2019; Attia et al., 2021; Pavanello et al., 2021; Zhang et al., 2020). Central Asia, with its rising summer temperatures, faces growing risks of heat stress (Wang, et al., 2023), highlighting the urgent need for effective adaptation strategies, particularly in households. While much research on the adaptation of Central Asian households has focused on the broader impacts of heat waves on agriculture (Liu, et al., 2020; Li et al., 2020) and public health (Tursumbayeva et al., 2023), less attention has been given to how households in the region adapt to extreme heat, particularly through their cooling choices. This gap is significant since household cooling strategies play a crucial role in mitigating the adverse effects of heat, promoting energy resilience, and reducing the health risks associated with high temperatures (Lee et al., 2024; Mushore et al., 2017). Moreover, Central Asia's energy access landscape is often characterized by frequent power outages and grid instability, particularly in rural areas (Mehta et al., 2024), although it has 100% electricity access. These interruptions may pose a significant barrier to the adoption of some cooling technologies. Understanding how these factors interact is crucial for informing policies that promote energy efficient cooling solutions while improving household resilience to heat stress.

This study investigates the factors that influence household cooling choices, focusing on the adoption of air-conditioning, fans, and sunscreen films, which are the primary cooling options utilized in Central Asia. By analyzing data from the "Household Access to Energy in the Fergana Valley" survey, which was conducted across the Kyrgyz Republic, Tajikistan, and Uzbekistan in 2023, this study investigates the socioeconomic, environmental, and power supply determinants of cooling choices. The study addresses the following research questions: (1) What are the determinants of household cooling choices in Central Asia? (2) How do climatic stress factors, particularly cooling degree days (CDD), influence household cooling technology choices? (3) In what ways does the reliability of the power supply affect households' decisions to adopt particular cooling technologies?

This study makes several contributions to the existing literature on environmental extremes, household cooling choices, and infrastructure in Central Asia and other arid regions. Firstly, while much of the current literature has examined heating choices, this study shifts the focus to cooling technologies, recognizing their increasing relevance in the context of rising global temperatures. To the best of our knowledge, this is the first study on cooling in Central Asia. Secondly, it assesses the role of power outages in cooling technology adoption. While air-conditioning is often seen as the most effective solution for heat adaptation, this research highlights that its adoption is limited in areas with frequent power disruptions. Lastly, the study explores the impact of climatic factors, specifically CDD, on household cooling choices. By incorporating CDD as a key variable, the research provides a clearer understanding of how climatic conditions influence household behavior and energy consumption patterns in response to heat stress.

The literature review provides an overview of existing research on the determinants of cooling technology adoption. The methodology section then outlines the data sources and empirical strategy, including the specification of the multinomial probit model. Attention is given to the variables of interest (cooling degree days and power outages), along with a detailed description of control variables. A discussion of empirical findings is followed by a robustness analysis to evaluate the impact of the duration of power outages on household cooling choices. Finally, the conclusion summarizes the key findings and highlights policy implications.

2. Literature Review

The growing global demand for cooling technologies in response to heat waves is extensively analyzed in the literature, particularly in the context of urbanization and its socioeconomic implications (Thomson et al., 2019; Attia et al., 2021; Zhang et al., 2020; Pavanello et al., 2021; Nematchoua et al., 2019). As cities expand and heat waves become more frequent and severe, the need for effective cooling solutions is becoming increasingly pressing (Mushore et al., 2017; Bardhan et al., 2020; Jia et al., 2024).

Hu et al. (2020) conducted a nationwide online survey in the People's Republic of China to explore the changing patterns of cooling in urban households and the factors that influence this transition. Yan and Liu (2020) modeled residential air-conditioner usage, emphasizing the role of historical temperature data in forecasting energy consumption. Zhang et al. (2020) explored the implications of climate change on air-conditioning (AC) usage in rural areas, highlighting the need to promote high efficiency AC units since low efficiency technologies were exacerbating rising energy demand.

Pavanello et al. (2021) drew attention to the risks posed by rising global temperatures, particularly for populations in low- and middle-income countries. While AC is viewed as a critical adaptation tool, access remains limited for lower income households. They find that AC adoption follows an S-shaped curve, influenced by socioeconomic conditions. This suggests that many low-income households will remain unable to afford such technologies, thereby creating an “adaptation cooling deficit”. These findings highlight the vulnerability of low-income populations, who often lack access to air-conditioning and thereby become more susceptible to the adverse health impacts of extreme heat (Mushore et al., 2017).

Research by Zander et al (2023) on the socioeconomic dimensions of cooling preferences reveals significant variation in behaviors, influenced by factors such as age, household composition, and heat tolerance. Their work suggests that targeting energy efficient cooling solutions based on these demographic factors could enhance energy resilience. Zhang et al. (2020) highlight the role of CDDs in driving air-conditioner use in rural areas, with socioeconomic variables such as dwelling characteristics influencing behavior.

In the context of access to electricity and demand for cooling, Falchetta and Mistry (2021) emphasize the necessity for decision-makers to integrate cooling needs into electricity access policies and power generation planning. They argue that recognizing these needs is critical for forecasting future residential electricity demand.

Thomson et al. (2019) argue for a reevaluation of energy policy frameworks, particularly in the context of year-round vulnerability to heat. Meles (2020) highlights the often overlooked issue of electricity supply reliability in developing countries. Focusing on urban households, the study critiques the prevailing narrative that equates electricity access with effective electrification. Meles emphasizes that without a reliable electricity supply, the benefits of electrification are not fully realized since frequent power outages result in households incurring additional expenditures to compensate.

Power outages present a unique challenge to households in developing countries. Lee et al. (2024) highlight the shortcomings of passive cooling measures under extreme heat conditions and the critical role of air-conditioning to ensure thermal comfort during power outages. Their study underscores the need for both passive and active cooling solutions to protect vulnerable populations from heat-related health risks.

Despite the extensive literature on cooling demands and energy resilience, studies on the influence of power outages on household cooling decisions remain limited, particularly with respect to Central Asia. This study aims to fill this gap by examining the interplay between CDDs, power outages, and household cooling choices in the Kyrgyz Republic, Uzbekistan, and Tajikistan. By exploring how households in these countries adapt their cooling strategies to power outages and increasing temperatures, this research offers insights into the socioeconomic and behavioral dimensions of energy resilience in Central Asia.

3. Methodology

3.1 Data

This study utilizes data from the 2023 Household Access to Energy in the Fergana Valley survey, which was conducted by the Central Asia Regional Economic Cooperation Institute (CAREC) in partnership with the Asian Development Bank Institute (ADBI) and the Public Opinion Research Institute in Kazakhstan. A total of 1,522 respondents were interviewed in July-August 2023, comprising 522 respondents in the Kyrgyz Republic, 500 in Tajikistan and 500 in Uzbekistan. The survey aimed to generate detailed data about energy access in a relatively compact and comparable area that spans parts of Uzbekistan, the Kyrgyz Republic, and Tajikistan. It gathered detailed information on energy use for various purposes, as well as the sociodemographic characteristics of heads of households. Among other things, the survey included detailed information on household cooling systems and the reliability of power. More information about the survey can be found in Holzhacker et al. (2024); Sulaimanova, Azhgaliyeva and Holzhacker (2024); Azhgaliyeva, Holzhacker, Rahut, and Correia (2024); and Azhgaliyeva, Kodama and Holzhacker (2025).

To analyze cooling demand in the context of climate change, CDD data were incorporated into the study. These meteorological data, sourced from the NASA POWER Project, are freely available.

3.2 Model Specification

To analyze the factors influencing household cooling choices, we employ a multinomial probit model, which accounts for multiple categorical outcomes. In this study, the categorical outcomes represent the choice of cooling system. The base category is households without any cooling system, against which the likelihood of adopting (i) air-conditioning and/or (ii) fans and/or sunscreen films (without air-conditioning) is estimated. The model allows the estimation of the probability that a household will select one of the available cooling options based on a set of explanatory variables. The general form of the multinomial probit model is as follows:

$$\Pr\left(y_i = m \mid X_i, \beta, u_{ij}\right) = \Phi\left(y_i = m,\ X_i\beta_j + u_{ij}\right) = \frac{\exp\,(X_i\beta_m + u_{im})}{\sum_{j=1}^{J}\exp\,(X_{it}\beta_j + u_{ij})} \quad (1)$$

where:

- $\Pr\left(y_i = m \mid X_{it}, \beta, u_{ij}\right)$ is the probability that household i adopts cooling technology j, where m=1 refers to air-conditioning, m=2 refers to fans or sunscreen films (without air-conditioning), and m=3 refers to no cooling system (base outcome).
- X_i represents the set of explanatory variables for household i.
- β_j are the coefficients to be estimated for each cooling technology j.

- Φ denotes the cumulative distribution function of the standard normal distribution, used to model the likelihood of different outcomes.

The multinomial probit model is estimated using maximum likelihood estimation (MLE), which enables the simultaneous estimation of the probabilities of each household choosing one of the three cooling system options. These probabilities are conditioned on household characteristics, power supply variables, and CDD conditions.

The analysis is performed on both the total sample and subsamples, including urban versus rural households and male-headed versus female-headed households. This approach allows the exploration of heterogeneity in cooling technology adoption across different demographic and geographic groups.

Sensitivity analyses are conducted to assess the stability of the estimated coefficients in the main model. This is done by incorporating the duration of power outages, thus providing a more nuanced understanding of the relationship between electricity reliability and the adoption of cooling technologies, as well as testing the robustness of the estimated coefficients.

Outcome Variable

Table 1 presents the descriptive statistics for the outcome variable, summarizing household cooling preferences across the three countries as well as for the total sample. Option 1, air-conditioning, is the least common in the Kyrgyz Republic, where only 9.20% of households have selected it as their primary cooling method. Adoption rates for air-conditioning are higher in Tajikistan (35.40%) and Uzbekistan (20.60%).

Table 1. Descriptive Statistics of Outcome Variable–Household Cooling Options

Outcome Variable	**Country**			
Household cooling choices	**Kyrgyz Republic**	**Tajikistan**	**Uzbekistan**	**Total**
Option 1 - air-conditioning	48	177	103	328
	9.20%	**35.40%**	**20.60%**	**21.55%**
Option 2 - fan or sunscreen films for windows	264	147	325	736
(without air-conditioning)	**50.57%**	**29.40%**	**65.00%**	**48.36%**
Option 3 - no cooling system	210	176	72	458
	40.23%	**35.20%**	**14.40%**	**30.09%**
Total	522	500	500	1522
	100%	**100%**	**100%**	**100%**

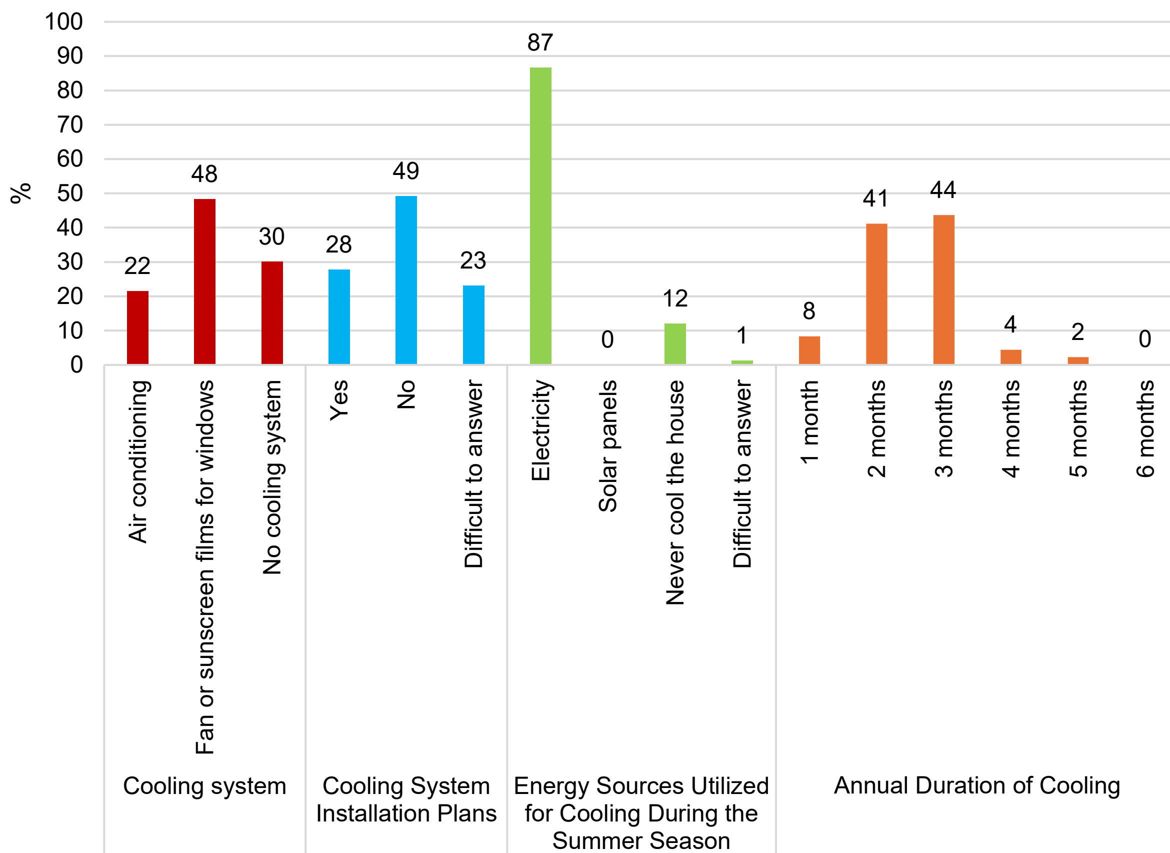
Note: First row has frequencies and second row has column percentages.
Source: Authors' calculations using data from 2023 Household Access to Energy in the Fergana Valley survey.

Option 2, fans and/or sunscreen films for windows (without air-conditioning), is more prevalent, accounting for 48.36% of households covered by the survey. In Uzbekistan, 65% of households have adopted this method, while the proportion drops to 50.57% in the Kyrgyz Republic and 29.40% in Tajikistan.

Some 14.40% of surveyed households in Uzbekistan have no cooling system. The corresponding figures in Tajikistan and the Kyrgyz Republic are higher at 35.20% and 40.23%, respectively, suggesting increased household vulnerability to heat in those two countries.

Approximately 49% of surveyed households lacking cooling systems reported no intention of altering their existing cooling methods (Figure 1). Among those using cooling technologies, electricity is the primary energy source, utilized by 87% of households during the summer cooling season, which in the Fergana Valley typically lasts for two to three months.

Figure 1. Household Cooling System Adoption, Energy Sources, and Usage Duration

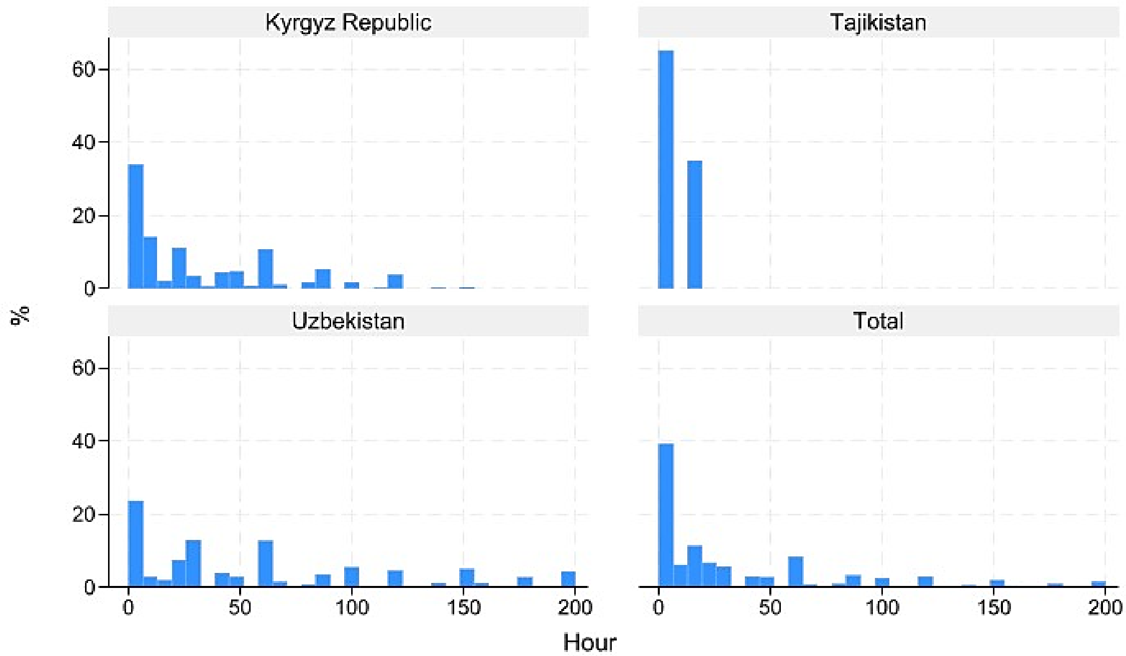


Source: Authors' calculations using data from 2023 Household Access to Energy in the Fergana Valley survey.

Power Supply

Tables 2 and 3 present statistics for key variables related to the frequency and duration of power outages experienced by households in the survey area, respectively. According to the survey statistics, the majority of households (about 64%) report the occurrence of scheduled or rolling blackouts, as indicated by the binary variable for blackouts (Table 2). This suggests that power supply interruptions are commonly experienced by a significant portion of the population. However, power outages are longer in the Kyrgyz Republic and Uzbekistan than in Tajikistan.

Figure 2. Average Monthly Duration of Power Outages
(hours, %)



Source: Authors' calculations using data from 2023 Household Access to Energy in the Fergana Valley survey.

Table 2. Descriptive Statistics for Scheduled or Rolling Blackouts
(1 = power outages)

	N	Mean	Std. Dev.	Min	Max
Total sample	1,522	0.6399	0.4801	0	1
Kyrgyz Republic	522	0.6609	0.4738	0	1
Tajikistan	500	0.4860	0.5003	0	1
Uzbekistan	500	0.7720	0.4199	0	1

Source: Authors' calculations using data from 2023 Household Access to Energy in the Fergana Valley survey.

Table 3 presents data on the duration of power outages, with the analysis based on responses from 1,398 households, as 124 respondents indicated "difficult to answer" for this question. The findings reveal that the average monthly duration of power outages is approximately 33 hours, with a standard deviation of 45 hours, reflecting substantial variation across households. While some households experience minimal disruptions, others endure prolonged outages, with the maximum reported duration reaching 200 hours. Uzbekistan exhibits the highest average outage duration among the surveyed countries, underscoring the severity of power supply challenges in specific regions.

Table 3. Descriptive Statistics for Average Monthly Duration of Power Outages

	N	Mean	Std. Dev.	Min	Max
	Total Sample				
Average monthly duration of power outages (hours)	1,398	33.0215	45.5055	0	200
Duration of power outages: 0	1,398	0.392	0.4884	0	1
– Duration of power outages: 1-16	1,398	0.1738	0.3791	0	1
– Duration of power outages: 17-50	1,398	0.1867	0.3898	0	1
– Duration of power outages: 50-200	1,398	0.2475	0.4317	0	1
	Kyrgyz Republic				
Average monthly duration of power outages (hours)	522	30.4866	35.228	0	150
– Duration of power outages: 0	522	0.3391	0.4739	0	1
– Duration of power outages: 1-16	522	0.1609	0.3678	0	1
– Duration of power outages: 17-50	522	0.2414	0.4283	0	1
– Duration of power outages: 50-200	522	0.2586	0.4383	0	1
	Tajikistan				
Average monthly duration of power outages (hours)	395	5.5899	7.638	0	16
– Duration of power outages: 0	395	0.6506	0.4774	0	1
– Duration of power outages: 1-16	395	0.3494	0.4774	0	1
– Duration of power outages: 17-50	395	0	0	0	0
– Duration of power outages: 50-200	395	0	0	0	0
	Uzbekistan				
Average monthly duration of power outages (hours)	481	58.2994	58.0112	0	200
– Duration of power outages: 0	481	0.237	0.4257	0	1
– Duration of power outages: 1-16	481	0.0437	0.2045	0	1
– Duration of power outages: 17-50	481	0.2807	0.4498	0	1
– Duration of power outages: 50-200	481	0.4387	0.4967	0	1

Source: Authors' calculations using data from 2023 Household Access to Energy in the Fergana Valley survey.

Cooling Degree Days

To assess the impact of climatic conditions on household cooling choices in Central Asia, this study integrates household survey data with meteorological data from the NASA Langley Research Center Prediction of Worldwide Energy Resources (POWER) Project. The POWER Project, funded through the NASA Earth Science/Applied Science Program, provides high-resolution temperature data essential for understanding regional variations in cooling needs.

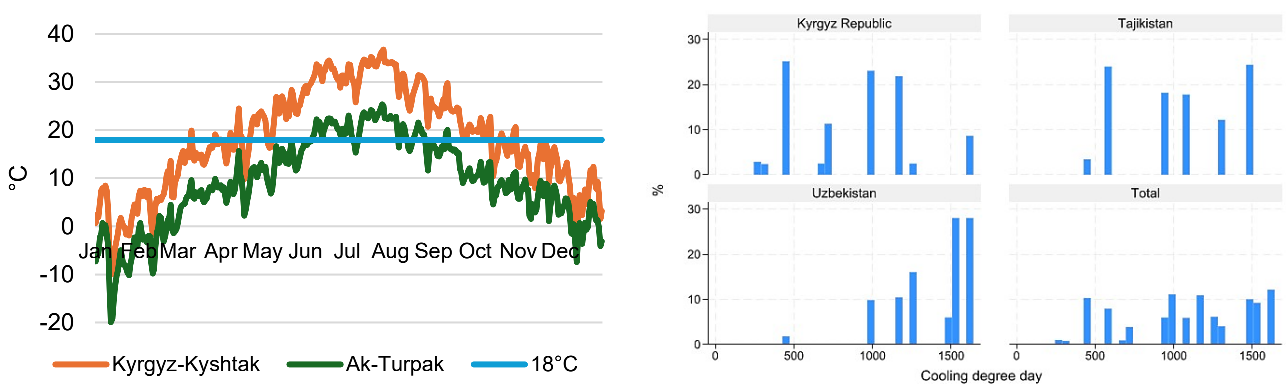
The matching process involved aligning household survey data with corresponding regional meteorological data from the POWER Project across 93 regions from Fergana Valley in Central Asia in 2023 (Appendix Table A2). The dataset includes daily temperature records at a height of 2 meters above the ground for the year 2023. To quantify cooling demand, CDDs were calculated for each region using a base temperature of 18°C for the entire year in 2023. CDDs serve as a measure of cumulative heat exposure (Falchetta et al., 2024), representing the total number of degrees by which daily average temperatures exceed the specified base temperature. The choice of 18°C as a reference temperature is consistent with previous studies analyzing the impact of climate on cooling demand (Zhang et al., 2020; Radhi & Sharples, 2013; Pavanello et al., 2021). This approach ensures methodological robustness and enables a comprehensive assessment of the relationship between climate variability and household.

Table 4. Descriptive Statistics for Cooling Degree Days by Countries for 2023

	Mean CDD	Standard Deviations	Number of regions	Number of households	Min	Max
Kyrgyz Republic	892.5	378.8	35	522	246	1,640
Tajikistan	1044.7	351.7	8	500	435	1,500
Uzbekistan	1403.8	243.2	50	500	468	1,641
Total	1110.5	393.9	93	1,522	246	1,641

CDD=cooling degree days.
Note: The cooling season (temperature above 18°C) is mainly during May–September. Although Fergana Valley is a small part in Central Asia, the number of CDD varies from 246 (Ak-Turpak) to 1640 (Kyrgyz-Kyshtak) (Figure 3). Approximately one-third of surveyed households live in regions with CDD of 1,500 and above, which is considered high. More households live in hotter regions in Uzbekistan (nearly all are around 1,000 CDD or higher).
Source: Authors' calculations using data obtained from the POWER Project's Hourly v2.4.9 on 2025/02/21 https://power.larc.nasa.gov/data-access-viewer/.

Figure 3. Daily Temperature



Source: Authors' calculations using data obtained from the POWER Project's Hourly v2.4.9 on 2025/02/21 https://power.larc.nasa.gov/data-access-viewer/.

Table 4 presents the descriptive statistics for CDDs across three Central Asian countries. CDDs occur mainly in May–September in the regions with most CDDs (Figure 3). A shorter period with many CDDs indicates intense cooling needs over a few months. The mean CDD values reveal significant geographical differences in cooling demand across the three countries. Uzbekistan has the highest mean CDD at 1,403.89, indicating that it experiences the most intense heat exposure relative to the other countries in the region. By comparison, the Kyrgyz Republic has the lowest mean CDD at 892.57, suggesting relatively less extreme heat exposure, but with a higher standard deviation (378.86), indicating greater variability in heat exposure, likely due to the country's diverse terrain and altitudinal variations. Tajikistan also has a relatively high standard deviation (351.73), further indicating regional diversity in temperature extremes within the country. These statistics highlight the uneven distribution of heat stress across different regions in Central Asia, indicating that cooling needs may vary significantly depending on geographic location within each country.

Control Variables

Table 5 provides an overview of the demographic and socioeconomic characteristics of the surveyed households. These are used as control variables in the model that examines factors influencing household cooling choices. The correlation matrix of control variables is presented in Appendix Table A1.

The mean age of the heads of household is 40.93 years, with a standard deviation of 14.98 years, indicating a relatively wide distribution of ages across the sample. The gender distribution of heads of household is nearly equal by sample design, in order to allow for gender comparison: 50.1% of surveyed household heads are male, while 77.3% are married.

Heads of the surveyed households display a range of educational attainment. The highest education level achieved was secondary school (11 classes) for 39.5%, secondary specialized or vocational education for 27.4%, and higher education (ranging from a bachelor's degree to PhD) for 26.2%. Only 6.9% did not complete secondary education.

While 36.6% of the surveyed households are situated in urban areas, the majority (63.4%) are in rural areas. The average household size is 5.41 members, with individual households ranging from 1 to 19 members. The average proportion of children under 16 years old in households is 32.1%, with a standard deviation of 20.6%, ranging from 0 to 80%. The average proportion of senior members (58 years and older) in households is 14.4%, with a standard deviation of 19.8%, and range spanning from 0% to 100%.

Table 5. Descriptive Statistics for Control Variables

	Number of obs.	Mean	Std. Dev.	Min	Max
Household head age (years)	1,522	40.932	14.98	18	85
Household head gender (1=male)	1,522	0.501	0.500	0	1
Marital status (1=married)	1,522	0.773	0.419	0	1
Education level:					
– Incomplete secondary (9 classes)	1,522	0.069	0.254	0	1
– Secondary (11 classes)	1,522	0.395	0.489	0	1
– Secondary specialized and vocational education (college, technical school)	1,522	0.274	0.446	0	1
– Higher education (specialist, bachelor, master, candidate, doctor, PhD)	1,522	0.262	0.440	0	1
Household size	1,522	5.405	2.227	1	19
Share of children in household	1,522	0.321	0.206	0	0.8
Share of seniors in household	1,522	0.144	0.198	0	1
Household income level:					
– Low	1,522	0.132	0.338	0	1
– Middle	1,522	0.239	0.426	0	1
– Higher	1,522	0.512	0.500	0	1
Residence (1=City)	1,522	0.366	0.482	0	1

Source: Authors' calculations using data from 2023 Household Access to Energy in the Fergana Valley survey.

Some 23.9% of households are categorized as “middle-income”, defined as having a household income of 12,001-20,000 som in the Kyrgyz Republic, 1,401–2,400 somoni in Tajikistan, or 2,000, 001–3,200,000 sum in Uzbekistan. Slightly more than half (51.2%) of households fall within the “higher” income level (more than 20,000 som, 2,400 somoni, or 3,200 000 sum).

4. Empirical Findings

4.1 Main Model

Table 6 presents the estimation results of the multinomial probit analysis, which examines the determinants of household choices regarding cooling technologies using full sample (column 1) and subsamples of urban and rural (columns 2–3), and households headed by male and female (columns 4–5). The results are provided for the adoption of air-conditioning or fans and sunscreen films (without air-conditioning), with *“no cooling system”* serving as the base (reference) outcome for interpretation. These outputs present insights into how socioeconomic and demographic factors, environmental conditions, and power supply reliability affect the likelihood of households choosing air-conditioning or alternative solutions, such as fans and sunscreen films, to cool their homes.

Air-conditioning

One of the key variables of interest, CDD, exhibits a statistically significant influence on household decisions to adopt air-conditioning. This effect is particularly pronounced in samples where households are located in urban areas and in male-headed households.

Conversely, the second key variable—power outages, measured by the prevalence of scheduled or rolling blackouts—has a negative impact on air-conditioning adoption. This underscores the critical role of reliable electricity access as a prerequisite for adopting energy intensive cooling systems.

Households with higher levels of education, particularly those where the head of household possesses tertiary education, are more likely to adopt air-conditioning. This finding is consistent across urban and rural areas, although the effect is stronger in cities. Higher-income households also exhibit a greater propensity to choose air-conditioning. Middle- and high-income groups show significant positive associations with the likelihood of air-conditioning adoption, underscoring the role of affordability in accessing this cooling technology. Urban residency further amplifies the preference for air-conditioning. Households with more children are less inclined to adopt air-conditioning, possibly reflecting economic constraints in larger families. Meanwhile, the presence of senior members in households is positively associated with air-conditioning adoption (though at a 10% significance level), potentially due to the higher vulnerability of older individuals to heat stress.

Fans or Sunscreen Films (Without Air-conditioning)

Climatic conditions, as captured by the log of CDDs, significantly drive the preference for fans or sunscreen films. Households in regions experiencing more extreme or prolonged heat are more likely to adopt such methods, underscoring the role of climatic factors in shaping preferences for this cooling system.

Unlike the case for air-conditioning, power outages (scheduled or rolling blackouts) do not significantly deter households from selecting fans or sunscreen films, reflecting the lower energy dependency of these alternatives.

The preference for fans or sunscreen films (without air-conditioning) as a cooling method is influenced by household size, with larger households more likely to opt for this alternative. This may be attributable to the relatively lower costs and energy demands associated with these options, making them more suitable for households with greater economic constraints. Though less influential (only at 10% level of significance) than for air-conditioning (at 5% level of significance), income still plays a role, with middle-income households showing a positive but weaker association with the adoption of fans or screens (as opposed to having no cooling method). Income has no significant impact at 5% level of significance on the likelihood of having fans or sunscreens, probably due to their greater affordability than air-conditioning. An increase in household size is associated with a higher probability of adopting fans and/or sunscreen films as cooling technologies. However, a greater number of children in the household negatively affects the likelihood of choosing these cooling methods, mirroring the pattern observed for air-conditioning. In other words, households with more children are more likely to have no cooling method at all.

These empirical findings reveal that the adoption of air-conditioning is predominantly driven by higher education and income, along with urban residency and reliable power supply and climatic conditions, while the adoption of fans or sunscreen films is predominantly driven by household size and climatic factors. These findings underscore the importance of addressing the infrastructural challenges such as the unreliability of electricity supply to ensure equitable access for cooling solutions in Central Asia.

Table 6. Multinomial Probit Model Coefficient Estimates for Household Cooling Choices (Main Model)

	Total Sample	**HH Residence**		**HH Head Gender**	
		Urban	*Rural*	*Male*	*Female*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
		Air-conditioning			
HH head age	-0.005	-0.001	-0.008	-0.007	-0.004
	(0.004)	(0.007)	(0.005)	(0.006)	(0.006)
HH head gender (1=male)	0.026	0.109	0.007		
	(0.116)	(0.190)	(0.150)		
Tertiary education level	0.755***	1.125***	0.563***	0.429**	1.188***
	(0.128)	(0.214)	(0.166)	(0.174)	(0.196)
Household size	0.032	0.079	0.020	-0.029	0.099**
	(0.030)	(0.052)	(0.038)	(0.043)	(0.045)
Share of children in HH	-0.950***	-1.698***	-0.548	-0.822*	-1.034**
	(0.329)	(0.524)	(0.431)	(0.459)	(0.486)
Share of seniors in HH	0.538*	0.102	0.761*	0.308	0.831*
	(0.322)	(0.536)	(0.412)	(0.454)	(0.461)
Middle income level	0.401**	0.667**	0.370*	0.252	0.587**
	(0.174)	(0.302)	(0.224)	(0.246)	(0.254)
Highest income level	0.475***	0.170	0.680***	0.374*	0.572***
	(0.146)	(0.235)	(0.192)	(0.208)	(0.212)
Residence (1=urban)	0.456***			0.528***	0.417**
	(0.126)			(0.175)	(0.183)
Log CDD	**0.381*****	**0.614****	**0.287***	**0.542*****	**0.177**
	(0.145)	**(0.289)**	**(0.173)**	**(0.197)**	**(0.221)**
Scheduled or rolling blackouts (1 = power outages)	**-0.260****	-0.219	**-0.288***	-0.240	**-0.302***
	(0.121)	(0.196)	**(0.157)**	(0.169)	**(0.176)**
Country fixed effects	+	+	+	+	+
Constant	-3.942***	-4.940**	-3.463***	-4.376***	-3.312**
	(0.993)	(1.975)	(1.184)	(1.329)	(1.512)
		Fans and/or sunscreen films (without air-conditioning)			
HH head age	-0.002	-0.000	-0.003	-0.004	-0.000
	(0.004)	(0.007)	(0.004)	(0.005)	(0.005)
HH head gender (1=male)	-0.001	0.126	-0.057		
	(0.101)	(0.179)	(0.124)		
Tertiary education level	0.068	0.273	-0.007	-0.046	0.191
	(0.122)	(0.216)	(0.151)	(0.165)	(0.186)
Household size	0.079***	0.116**	0.059*	0.024	0.130***
	(0.026)	(0.048)	(0.031)	(0.035)	(0.039)
Share of children in HH	-0.694**	-1.438***	-0.288	-0.357	-0.956**
	(0.287)	(0.483)	(0.363)	(0.413)	(0.407)
Share of seniors in HH	0.160	-0.464	0.463	0.238	0.124
	(0.298)	(0.516)	(0.367)	(0.427)	(0.414)
Middle income level	0.275*	0.491*	0.255	0.287	0.235
	(0.151)	(0.277)	(0.187)	(0.221)	(0.209)
Highest income level	0.011	-0.253	0.178	-0.026	0.027
	(0.131)	(0.224)	(0.165)	(0.191)	(0.183)
Residence (1=urban)	-0.114			-0.044	-0.159
	(0.113)			(0.160)	(0.163)
Log CDD	**0.435*****	0.181	**0.553*****	**0.520*****	**0.352***
	(0.130)	(0.256)	**(0.153)**	**(0.181)**	**(0.188)**
Scheduled or rolling blackouts (1 = power outages)	0.025	0.095	-0.039	-0.010	0.068
	(0.107)	(0.187)	(0.132)	(0.148)	(0.155)
Country fixed effects	+	+	+	+	+
Constant	-2.947***	-1.333	-3.777***	-3.198**	-2.670**
	(0.910)	(1.791)	(1.073)	(1.250)	(1.328)

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	Total Sample	HH Residence		HH Head Gender	
		Urban	*Rural*	*Male*	*Female*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
Number of obs.	1522	557	965	763	759
Log likelihood	-1405.14	-516.69	-875.18	-706.23	-687.05
Chi^2	337.83	138.08	199.27	179.18	174.87
Probability	0.000	0.000	0.000	0.000	0.000

CDD=cooling degree days, HH=households.

Note: Base outcome is “no cooling system”. Robust standard errors are presented in parentheses. *p<0.10; **p<0.05; ***p<0.010

Source: Authors’ calculations using data from 2023 Household Access to Energy in the Fergana Valley survey.

4.2 Robustness Analysis: Power Outage Duration

The multinomial probit model estimates in Table 7 examine the factors influencing households’ choices of cooling systems under varying power outage durations. To test the robustness and sensitivity of our findings, we replace the binary dummy variable for power outages used in the main model with a categorical variable representing different durations: (i) 1–16 hours, (ii) 17–50 hours, and (iii) 50–200 hours.

It is important to note that data on power outage duration was incomplete, as 126 households responded with “difficult to answer,” resulting in missing observations. Consequently, the estimation sample is reduced to 1,398 observations. Despite the reduction in the number of observations, the estimated effects of the control variables remain consistent and statistically significant. This suggests that incorporating a more detailed measure of power outage duration does not alter the key relationships identified in the main model, reinforcing the robustness of our results.

As in the main model, the duration of power outages significantly and negatively influences households’ likelihood of adopting air-conditioning systems, particularly in rural areas. This finding highlights the practical constraints that prolonged power outages impose on the functionality and utility of energy-intensive appliances, making them less feasible for households that face frequent or extended power disruptions. By contrast, the influence of power outage duration on the adoption of less energy-intensive cooling options (fans or sunscreen films), is less pronounced, as it is in the main model findings. This suggests that households facing prolonged power outages may prioritize alternative cooling methods that are less dependent on a stable electricity supply.

The CDD variable also exhibits results similar to those in the main model when the dummy variable for power outages is replaced. CDD remains positively significant, indicating that households are more likely to adopt cooling solutions in response to climatic stress and the immediate need for thermal comfort.

Table 7. Multinomial Probit Model Coefficient Estimates (Power Outage Duration)

	Total Sample	HH Residence		HH Head Gender	
		Urban	*Rural*	*Male*	*Female*
		Air-conditioning			
HH head age	-0.006	-0.000	-0.010*	-0.005	-0.007
	(0.004)	(0.007)	(0.006)	(0.006)	(0.007)
HH head gender (1=male)	0.121	0.144	0.138		
	(0.123)	(0.199)	(0.161)		
Tertiary education level	0.786***	1.070***	0.622***	0.421**	1.237***
	(0.136)	(0.223)	(0.179)	(0.185)	(0.208)
Household size	0.029	0.021	0.040	-0.028	0.084*
	(0.032)	(0.054)	(0.039)	(0.045)	(0.047)
Share of children in HH	-0.838**	-1.410***	-0.570	-0.552	-1.208**
	(0.346)	(0.539)	(0.463)	(0.485)	(0.503)
Share of seniors in HH	0.517	-0.172	0.876**	0.410	0.632
	(0.339)	(0.548)	(0.440)	(0.475)	(0.481)
Middle income level	0.368**	0.660**	0.310	0.222	0.547**
	(0.186)	(0.315)	(0.242)	(0.263)	(0.271)
Highest income level	0.318**	0.157	0.467**	0.249	0.415*
	(0.158)	(0.249)	(0.212)	(0.227)	(0.228)
Residence (1=urban)	0.463***			0.466**	0.497**
	(0.132)			(0.183)	(0.194)
Log CDD	**0.414*** **	**0.538***	**0.311***	**0.604*** **	0.193
	(0.154)	**(0.304)**	**(0.187)**	**(0.204)**	(0.242)
Duration of power outages: 1-16 hours	-0.051	-0.209	0.007	0.207	-0.325
	(0.164)	(0.275)	(0.204)	(0.228)	(0.238)
Duration of power outages: 17-50 hours	**-0.455** **	-0.119	**-0.736** **	-0.413	**-0.544***
	(0.201)	(0.292)	**(0.302)**	(0.262)	**(0.320)**
Duration of power outages: 50-200 hours	-0.132	0.001	-0.221	-0.234	-0.098
	(0.187)	(0.280)	(0.263)	(0.264)	(0.276)
Country fixed effects	+	+	+	+	+
Constant	-4.128***	-4.306**	-3.583***	-4.879***	-3.045*
	(1.063)	(2.079)	(1.287)	(1.383)	(1.664)
		Fand and/or Sunscreen Films			
HH head age	-0.005	-0.003	-0.006	-0.005	-0.005
	(0.004)	(0.007)	(0.005)	(0.005)	(0.005)
HH head gender (1=male)	0.066	0.138	0.036		
	(0.105)	(0.186)	(0.130)		
Tertiary education level	0.086	0.262	0.020	-0.082	0.253
	(0.128)	(0.225)	(0.161)	(0.174)	(0.196)
Household size	0.075***	0.095*	0.055*	0.019	0.119***
	(0.027)	(0.050)	(0.033)	(0.036)	(0.040)
Share of children in HH	-0.566*	-1.390***	-0.102	-0.144	-0.992**
	(0.301)	(0.504)	(0.382)	(0.430)	(0.432)
Share of seniors in HH	0.122	-0.651	0.531	0.294	-0.051
	(0.312)	(0.525)	(0.392)	(0.448)	(0.430)
Middle income level	0.082	0.339	0.035	0.085	0.050
	(0.162)	(0.292)	(0.202)	(0.239)	(0.223)
Highest income level	-0.208	-0.390	-0.064	-0.224	-0.204
	(0.142)	(0.238)	(0.181)	(0.209)	(0.196)
Residence (1=urban)	-0.112			-0.087	-0.114
	(0.118)			(0.167)	(0.169)
Log CDD	**0.481*** **	0.228	**0.564*** **	**0.608*** **	**0.363***
	(0.137)	(0.269)	**(0.162)**	**(0.190)**	

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	Total Sample	HH Residence		HH Head Gender	
		Urban	*Rural*	*Male*	*Female*
Duration of power outages: 1-16 hours	0.197	-0.055	0.261	0.318	0.095
	(0.151)	(0.278)	(0.182)	(0.220)	(0.209)
Duration of power outages: 17-50 hours	0.066	0.353	-0.133	-0.073	0.207
	(0.162)	(0.261)	(0.209)	(0.225)	(0.238)
Duration of power outages: 50-200 hours	0.160	0.347	0.013	0.133	0.200
	(0.151)	(0.258)	(0.190)	(0.211)	(0.219)
Country fixed effects	+	+	+	+	+
Constant	-3.077***	-1.385	-3.672***	-3.691***	-2.366*
	(0.956)	(1.886)	(1.131)	(1.312)	(1.408)
Number of obs.	1398	524	874	704	694
Log likelihood	-1279.55	-484.21	-781.72	-645.67	-622.49
Chi2	314.69	126.73	187.85	170.49	157.59
Probability	0.000	0.000	0.000	0.000	0.000

CDD=cooling degree days, HH=households.
Note: Base outcome is “no cooling system”. Robust standard errors are presented in parentheses. *p<0.10; **p<0.05; ***p<0.010.
Source: Authors’ calculations using data from 2023 Household Access to Energy in the Fergana Valley survey.

5. Conclusion and Policy Implications

This study investigates the factors influencing household choices regarding cooling technologies in Central Asia, focusing on air-conditioning and fans/sunscreen films. Utilizing data from the “Household Access to Energy in the Fergana Valley” survey conducted in the Kyrgyz Republic, Tajikistan, and Uzbekistan, the analysis examines how socioeconomic, environmental, and power supply factors shape household decisions. Employing a multinomial probit model, this study analyzes the determinants for adopting different cooling technologies, highlighting the interaction between climatic conditions and power supply reliability. The research provides valuable insights into the factors shaping household cooling choices in Central Asia, with particular emphasis on the role of power supply infrastructure and climatic conditions. The findings underscore the importance of addressing both power sector reliability and climate adaptation in vulnerable regions. Key results include the significant impact of cooling degree days on cooling appliance adoption and the critical role of power outages in influencing the choice of cooling technologies.

First, a significant number of surveyed households (48.36%) rely on fans and/or sunscreen films for windows for cooling (without air-conditioning). In Uzbekistan, 65% of surveyed households have adopted this method, while the proportion drops to 50.57% in the Kyrgyz Republic and 29.40% in Tajikistan. Additionally, 14.40% of surveyed households in Uzbekistan have no cooling system. The corresponding figures in Tajikistan and the Kyrgyz Republic are higher at 35.20% and 40.23%, respectively, suggesting increased household vulnerability to heat in these two countries.

Second, cooling degree days significantly impact the adoption of cooling appliances. The cooling season primarily spans from May to September, with CDD ranging from 246 to 1,641 in the Fergana Valley. Approximately one-third of surveyed households live in regions with CDD 1,500 and above, which is considered high. Households in areas with higher CDD are more likely to adopt cooling solutions (air-conditioning, fans, or sunscreen films). The analysis underscores the importance of climatic conditions, particularly CDDs, in influencing cooling technology adoption. This finding highlights households’ adaptive behavior in response to climatic stress, demonstrating that cooling choices are shaped by both socioeconomic factors and environmental constraints.

Integrating climatic data such as CDD into the analysis of household energy choices provides critical insights into adaptive behavior under different environmental conditions.

Third, power outages negatively impact the adoption of energy-intensive cooling technologies like air-conditioning but have no effect on less energy-intensive options like fans and sunscreen films. Power stability is crucial for adapting to heat using energy-intensive technologies (e.g., air-conditioning) in hotter areas during the peak cooling months (May–September) in Central Asia. Fans and sunscreen films, which are less energy-intensive than air-conditioning, are more commonly used in areas where power outages are a significant concern. This result highlights the importance of power reliability for adopting energy-intensive cooling technologies, suggesting that air-conditioning adoption is constrained by economic and infrastructural barriers. It also emphasizes the importance of less energy-intensive cooling technologies (e.g., fans, sunscreen films, and other options not included in this study, such as energy efficiency measures and courtyards in building design) in regions with unreliable electricity access.

The study assessed the robustness of its findings by considering the duration of power outages with three dummy variables representing different outage durations. This analysis confirmed that the reliability of power supply plays a critical role in shaping cooling choices. Specifically, households in areas prone to frequent or prolonged power outages are less likely to adopt air-conditioning.

There are many measures for adapting to heat stress (Shen, Azhgaliyeva, and Baño Leal, 2024). We suggest several based on the study's results. Enhanced power supply reliability is crucial for supporting the adoption of energy-intensive cooling technologies like air-conditioning. Solar panels can help meet summer energy demand, as solar irradiation correlates with cooling needs, particularly in regions with high cooling requirements. Support can prioritize vulnerable households in regions with high heat exposure and unreliable power supply.

Based on this study, the following suggestions for future research are proposed. First, this study focused on a limited range of cooling solutions: air-conditioning, fans, and sunscreen films. Future research should explore additional heat adaptation options, such as building codes and passive cooling techniques in building design. These include improved insulation (Sulaimanova, Azhgaliyeva, and Holzhacker, 2024), reflective roofing, and natural ventilation, which can significantly reduce energy demand for cooling and aid in heat wave adaptation. If there is a need for such support, it should be accompanied by training for technicians and other stakeholders on the installation and maintenance of energy-efficient and passive cooling technologies. Additionally, location-specific cooling measures are important. Urban planning strategies, such as incorporating green spaces and water bodies, can reduce urban heat island effects and lower cooling demands. Community cooling centers can also provide immediate relief during heat waves. Second, while we identified the significant impact of power outages on cooling choices, we did not investigate the causes of these outages. Understanding the causes can help provide better policy recommendations to address power outages. Third, we did not take into account electricity tariffs and the impact of their growth. While the paper highlights power outages and grid instability as key barriers to adopting energy-intensive cooling technologies, another critical factor worth considering is the cost of electricity and its growth. The increase in electricity tariffs could significantly hinder the adoption and sustained use of air-conditioning, particularly among low- and middle-income households in rural areas, who are already financially constrained. Many rural households may already be opting for lower energy alternatives—such as fans and sunscreen films—to minimize electricity expenses.

APPENDIX

Table A1. Matrix of Correlations

	HH head age	HH head gender (1=male)	Tertiary education level	HH size	Share of children in HH	Share of seniors in HH	Middle income level	Highest income level	Residence (1=city)	CDD	Blackouts (1 = power outages)	Duration of power outages (hours)
HH head age	1											
HH head gender (1=male)	-0.008	1										
Tertiary education level	-0.067	0.078	1									
Household size	0.042	0.043	-0.067	1								
Share of children in HH	-0.049	-0.033	0.043	0.389	1							
Share of seniors in HH	0.329	0.032	-0.017	-0.043	-0.324	1						
Middle income level	-0.01	0.006	-0.043	-0.01	0.041	0.003	1					
Highest income level	-0.023	0.028	0.074	0.18	0.063	-0.097	-0.573	1				
Residence (1=city)	0.078	-0.042	0.04	-0.104	-0.04	-0.01	-0.083	0.008	1			
CDD	0.074	-0.053	0.011	-0.102	-0.153	0.096	-0.087	-0.132	0.171	1		
Scheduled or rolling blackouts (1 = power outages)	0.125	-0.017	-0.029	0.119	0.032	-0.032	-0.004	0.023	0.013	0.044	1	
Average monthly duration of power outages (hours)	0.143	-0.008	-0.05	0.051	-0.031	0.003	-0.001	-0.019	0.053	0.181	0.61	1

CDD=cooling degree days, HH=households.
Source: Authors' calculations using data from 2023 Household Access to Energy in the Fergana Valley survey.

Table A2. Descriptive Statistics for Cooling Degree Days by Region in 2023

Kyrgyz Republic			Tajikistan			Uzbekistan		
35 regions	**CDD**	***N***	**8 regions**	**CDD**	***N***	**50 regions**	**CDD**	***N***
Achi	739.14	13	Asht	1,500.06	54	Akhunboboev	1,525.67	10
Ak-Turpak partially	246.07	15	B. Gafurov	585.8	120	Amirabod	1,640.78	10
Andijan	1,183.37	13	Isfara	434.61	17	Andijan	1,183.37	10
Aral	1005.7	13	Istaravshan	1,088.72	89	Aral	1,005.7	10
Asanchek	468.36	13	J.Rasulov	944.34	45	Asaka	1,005.7	9
Batken	434.61	20	Khujand	1,292.56	61	Baghdad	1,640.78	10
Bazar-Korgon	297.58	12	Konibodom	1,500.06	68	Besarang	1,525.67	10
Beget	1,183.37	13	Spitamen	944.34	46	Bozorboshi	1,525.67	10
Byurgendyu	1,183.37	13				Chartak	1,625.48	10
Changyr-Tash	1,183.37	13				Chinabad	1,625.48	10
Dzhany-Abad	1,183.37	12				Chust	1,251.78	10
Jalal-Abad	739.14	20				Ertepa	1,625.48	10
Kara-Seget	468.36	13				Ezgulik	1,251.78	10
Kara-Suu	468.36	20				Fergana	1,525.67	10
Khauz	1005.7	13				Gaiston	1,625.48	10
Kochkor-Ata	1,183.37	25				Garmidan	1,525.67	10
Kolot	1,183.37	12				Girvon	1,625.48	10
Kyrgyz-Kyshtak	1,640.78	15				Karaskan	1,625.48	10
Kyumyush-Aziz	739.14	13				Khojaabad	1005.7	10
Kyzyl-Abad	468.36	13				Kokand	1,500.06	10
Langar	468.36	13				Korasuv	468.36	9
Madaniyat	468.36	13				Korayantok	1,005.7	10
Min-Chynar	1,640.78	15				Kurganteppa	1,005.7	10
Mogol-Korgon	1,183.37	13				Kuva	1,525.67	10
Munduz (Kyzyl-Tuu)	739.14	13				Kuvasai	1,525.67	10
Munduz (Saipidin Atabek)	667.19	13				Loison	1,525.67	10
Naiman	1,251.78	13				Margilan	1,525.67	10
Oktyabr	1,005.7	13				Maslahat	1,625.48	10
Osh city	1,005.7	45				Mirabad	1,183.37	10
Pakhtachi	1,005.7	13				Naiman	1,251.78	10
Telman	468.36	13				Namangan	1,625.48	10
Tepe Korgon	1,005.7	13				Nazarmahram	1,525.67	10
Zar-Tash	1,640.78	15				Okbilol	1,525.67	10
Zarbalik	468.36	13				Okmozor	1,183.37	10
Zhapalak	1005.7	10				Oktosh	1,251.78	10
						Olmos	1,251.78	10
						Poytug	1,183.37	12
						Rishtan	1,640.78	10
.						Sarikurgan	1,525.67	10
						Shahrikhan	1,525.67	10
						Tepakurgan	1,251.78	10
						Tinchlik	1,640.78	10
						Tulaboi	1,500.06	10
						Turakurgan	1,251.78	10
						Uchkuza	1,183.37	10
						Uychi	1,625.48	10
						Yaipan	1,500.06	10
						Yangikurgan	1,625.48	10
						Yozyovon	1,525.67	10
						Zvutkan	1,251.78	10
Total	**892.5696**	**522**	**Total**	**1,044.738**	**500**	**Total**	**1,403.894**	**500**

CDD=cooling degree days.
Source: Authors' calculations using the data was obtained from POWER Project's Hourly v2.4.9 on 2025/02/21 https://power.larc.nasa.gov/data-access-viewer/.

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Heat Adaptation in Central Asia

Household Cooling Choices

This study examines how households in the Kyrgyz Republic, Tajikistan, and Uzbekistan adapt their cooling strategies to power outages and increasing temperatures. It provides insights into the socioeconomic and behavioral dimensions of energy resilience in Central Asia. It notes the importance of a reliable power supply and the potential of solar panels to meet summer energy demands.

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